

# Institute for Manufacturing and Sustainment Technologies

# iMAST

Q U A R T E R L Y

2000 No.4

A U.S. Navy Manufacturing  
Technology Center of Excellence

## Chief of Naval Research Visits iMAST

As part of a recent visit to Penn State's Applied Research Laboratory, RAdm Jay Cohen, Chief of Naval Research visited the Institute for Manufacturing and Sustainment Technologies (iMAST). Admiral Cohen was able to receive a capabilities overview relative to on-going project efforts within the Navy ManTech Center of Excellence program located at ARL.

Rear Admiral Jay M. Cohen, USN became the 20th Chief of Naval Research (CNR), Office of Naval Research (ONR), on June 7, 2000. As Chief of Naval Research, Admiral Cohen manages the science and technology programs of the Navy and Marine Corps from basic research through manufacturing technologies.

In addition to his duties as CNR, Admiral Cohen also serves as Director, Test and Evaluation and Technology Requirements to the Chief of Naval Operations. He is also Deputy Commandant (Science and Technology), Headquarters, U.S. Marine Corps.

Admiral Cohen received his commission as an ensign upon graduation from the United States Naval Academy in 1968, where he was a Trident Scholar. After graduation, he qualified as a Navy diver with the SEALAB Group in San Diego, CA.

Following training at Submarine School, New London, CT, he reported to the USS *Diodon* (SS 349) in San Diego for duty as Supply and Weapons Officer. He next studied at the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution under the Navy's Burke Scholarship Program. He received a joint Ocean Engineering degree and Master of Science in Marine Engineering and Naval Architecture from MIT.

Admiral Cohen commanded the USS *Hyman G. Rickover* (SSN 709). Following command, the admiral served on the staff of the Commander in Chief, U.S. Atlantic Fleet, as senior member of the Nuclear Propulsion Examining Board, and the staff of the Director of Naval Intelligence at the Pentagon as Director of Operational Support. Admiral Cohen also commanded USS *L.Y. Spear* (AS 36) and her crew of 800 men

and 400 women from 1991 to 1993. During his tour, the *Spear* was awarded the Submarine Force Atlantic Fleet Battle Efficiency "E" Award and conducted an unscheduled five-month deployment to the Persian Gulf in support of Operation DESERT STORM that included repairs to over 48 U.S. and allied ships, recovery of an F/A-18 Hornet sitting in 190 feet of water off the coast of Iran, and humanitarian projects in Kuwait City.

In April of 1993, Admiral Cohen reported to the Secretary of the Navy staff for duty as Deputy Chief of Navy Legislative Affairs. In October 1997 he was promoted to the rank of Rear Admiral and reported to the Joint Staff for duty as Deputy Director for Operations. In June of 1999 he assumed duties as Director, Navy Y2K Project Office until assumption of his current duty as Chief of Naval Research.



iMAST Director, Bob Cook, explains a ManTech project effort to Admiral Cohen.



**FOCUS ON  
REPAIR  
TECHNOLOGY**

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## DIRECTOR'S CORNER

### Transition

I'm writing this as I am preparing to attend the Defense Manufacturing Conference 2000. In view of the fact that this will be my first time participating in the event, I'm



not sure what to expect. But I do look forward to learning more about Manufacturing Technology. I anticipate our team will discover several ways to improve the way we conduct business. Our sponsors, stakeholder, and system commands representatives will be in attendance. I expect some frank discussions about our performance with some recommendations on improvements. It should be extremely worthwhile.

We recently presented briefings on most of our ManTech projects to the Joint Directors Manufacturing

Technology Metals Subpanel. I was very pleased with the quality, progress, and conduct of the presentations. I received informal feedback that the Subpanel was very satisfied with a strong majority of the programs. The one area that needs to be improved is in the area of transitions. We need to put more emphasis on the implementation of our projects. With that in mind, one of my principal focuses will be TRANSITION. That is the primary criteria for project development as we move our program forward. Key on it!

I encourage active involvement by the technical assistants, systems command representatives, program offices, and industry. I expect the direction of our program to be guided by these individuals, within funding and schedule constraints. As we are "pushing the envelope" in our projects, I don't expect everything to proceed as planned. We must be flexible enough to respond to changes in requirements and funding, and adjust our plans accordingly—a key element!

In this quarterly newsletter we are focusing attention on our repair technology program. As the fleet ages, tight competition for procurement budget dollars continues. Keeping existing equipment operational is expensive, demanding considerable attention. Navy ManTech funds an effort dedicated to Repair Technology (RepTech). The iMAST center works with shipyards, depots, and logistic bases to implement improved processes that will reduce or avoid the costs involved in sustaining the fleet. Our feature article highlights laser cladding as a method for affordable repair of equipment that would otherwise be replaced at significant costs.

In preparation for fiscal year 2002 project new starts, I encourage you to review your programs for issues that could benefit from a different viewpoint. Our goal is to reduce the cost of procuring and maintaining equipment. We have dedicated scientists and engineers who know the latest technological advances. Since the iMAST review process is about to begin, issues must be entered into the issue database in order to receive consideration. Give us a call if we can be of assistance in helping you. My administrator, Greg Johnson, has the handle on that aspect of the program. He is available to assist you in any way possible. You may reach him at (814) 865-8207 or by e-mail at: [gjj1@psu.edu](mailto:gjj1@psu.edu). As always, I will look forward to any feedback you can provide me. Please contact me or my staff at any time. Best wishes for the coming new year.

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*Bob Cook*



### Focus on Repair Technology

# Laser Cladding for the U.S. Navy REPTECH Program

by Kenneth C. Meinert, Jr., Eric J. Whitney, Paul A. Blomquist

## Abstract

Repair engineering is a broad-based discipline that is not explicitly taught to students in the conventional sense of a recognized field such as mechanical or materials engineering. Individuals responsible for repair activities often must develop engineering methods that rely on classical engineering methods combined with an in-depth operational knowledge of the particular component or system being considered for repair. This article briefly discusses repair engineering as a discipline and provides a synopsis of two repair development programs. Specifically, the role of U.S. Navy's REPTECH program is discussed as a means to implement repair-engineering methodologies at locations that traditionally do not have formalized repair development activities.

## Introduction

In the world of engineered systems, structures and devices, the term 'repair' often defines different technical procedures. The repair of a system (e.g. an automobile), often consists of two related steps: troubleshooting and component replacement. Nearly all of us have all experienced (both positive and negative) this type of repair. Troubleshooting complex systems often is aided by technical manuals and specialized diagnostic equipment that have been created specifically for use during repair. Sometimes, components are not replaced because they can be refurbished, or made operational again, at a cost much less than the cost of a replacement component. An automobile example is the refurbishment of brake drums or rotors.

DoD systems are often highly complex consisting of many interrelated sub-systems. Maintenance and repair of these systems consumes a significant portion of DoD spending. As DoD systems age, the level of effort required to maintain and repair these system will increase, and there will a greater demand for the development of new repair and refurbishment procedures. The need for new repair and refurbishment processes will put increased demands on personnel responsible to develop, qualify, implement, perform, and certify such procedures.

Laser cladding has been used for refurbishment of components for a number of years, particularly in the civilian sector. Laser cladding offers the ability to rebuild damaged components with low thermal distortion, and low base metal dilution, while forming a structural metallurgical bond with the substrate. The cladding material can be varied to fit the needs of the application and often results in improved performance. This article discusses component level repair and refurbishment, and details successful repairs implemented on two

components: propulsion shafts for the Marine Corp Amphibious Assault Vehicle, and torpedo components, as well as details on a new project that involves repair of the vertical launch system (VLS) for submarines.

## Refurbishment of AAV Propulsion Shafts

The Marine Corps Amphibious Assault Vehicle (AAV) is designed to move men and equipment from ship to shore. While in the amphibious mode, two waterjet pumps propel the vehicle through the water. The impellers for the waterjet are driven by two propulsion shafts. A portion of the shaft is exposed during operation. As the vehicle nears the beach, sand and other hard particles are ingested into the pump resulting in uniform erosion of the shaft. Typical



A U.S. Marine Amphibious Assault Vehicle from Delta Company, 2nd Amphibious Assault Battalion, 2nd Marine Division, prepares to enter the well deck of the USS *La Moure County* (LST 1194), during Combined Joint Task Force Exercise '96.

damage can lead to metal loss of greater than 0.06 inches on the radius. When the shafts are worn beyond the serviceable limit, chromium electroplating is used to buildup the shaft diameter. The chromium electroplating process is slow,



## PROFILE

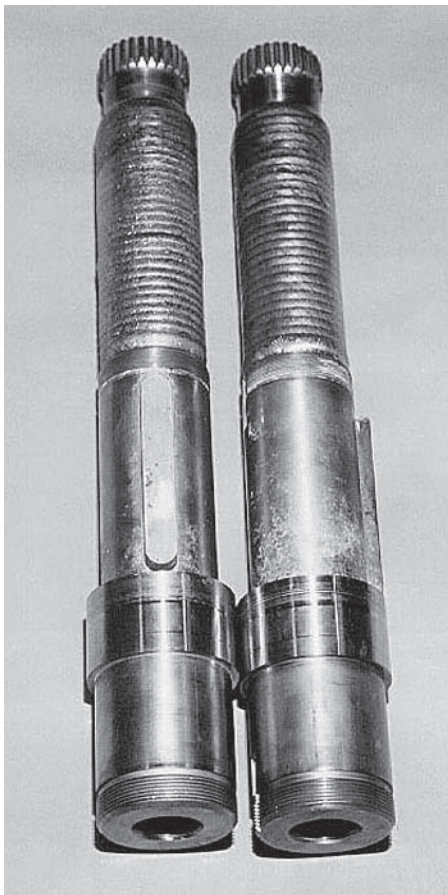
Ken Meinert has been employed at the Applied Research Laboratory for the past six years in the Laser Processing Division. His work has included development of laser welding, cutting, cladding, and surface treatment processes for a wide variety of defense-related items, including torpedo components, aircraft carrier trough covers, missile casings, tank heat exchangers, ordnance, and naval propellers. He has experience with a wide variety of materials, including aluminum, copper, nickel, and iron alloys as well as metal matrix composites.

Mr. Meinert received his B.S. and M.S. degrees in Engineering Science and Mechanics from the Pennsylvania State University. He is currently pursuing a Ph.D. in metallurgy. He can be reached at (814) 863-7281 or by e-mail at: <kcml04@psu.edu>.

(typically 15 hours are required to deposit 0.02 inches of material), is becoming more of an environmental issue (due to the toxicity of hexavalent chromium), and adds no load bearing capability to the substrate.

Laser cladding of AAV shafts was developed under a U.S. Navy RepTech program entitled "Laser Cladding as an Alternative to Chrome Plate for Land Vehicles".

The material chosen for the repair was 17-4PH stainless steel, the same material as the shaft. Metal powder was fused to the surface of the shaft through the use of a 3 kW continuous wave Nd:YAG laser. After laser cladding, the repaired area was locally heat treated to temper the clad and improve the susceptibility to stress corrosion cracking. Shafts were then machined to the original dimensions, successfully tested, and returned to service.



Laser-repaired AAV propulsion shafts with cladding completed, awaiting final machining.

## Torpedo Repair

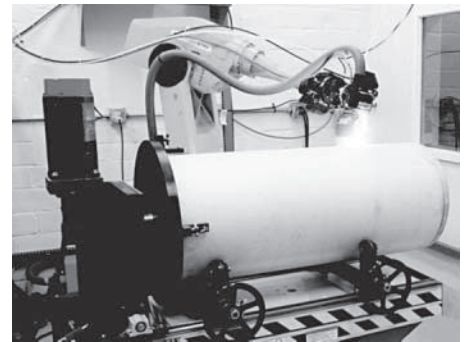
Repair of torpedo components is necessary because torpedoes are not just single use weapons. They are often used repeatedly in an exercise configuration for testing and training purposes. After the torpedo has completed the mission, it is recovered and sent for refitting. During these exercise operations damage occurs to the components due to operation, handling, and immersion in a seawater environment. Repair of components is performed at the Keyport Division of the Naval Undersea Warfare Center (NUWC) at Keyport, WA.

The current repair procedure for damage to the external surface of a torpedo shell involves the removal of the powder epoxy paint from the entire surface of the component, chemical removal of the anodized coating (if required), preparation of the damaged surface, and application of a polymer-based compound in the damaged areas. After the compound has cured, the surfaces are restored by hand finishing. The component is sent to be anodized (if the anodized coating had been removed previously), and finally sent to be repainted with a powder-based epoxy paint, thus completing the repair procedure.

There are several issues with the current repair method. First, the polymer-based repair method is neither structural nor permanent. The repair may become damaged during operation and is routinely lost during a refurbishment cycle (during paint removal). Therefore there is a need to repair any previous damage that has occurred to the component as well as any new damage, increasing the repair time with each successive refurbishment cycle. A second factor with the repair process is the anodized coating process. The anodized coating is formed by a conversion process that transforms some of the aluminum from the component into a durable protective layer. During removal of this coating, the coating containing aluminum that was transformed, as well as a small amount of aluminum from the surface is lost. After repeated processing, the amount of aluminum loss can exceed



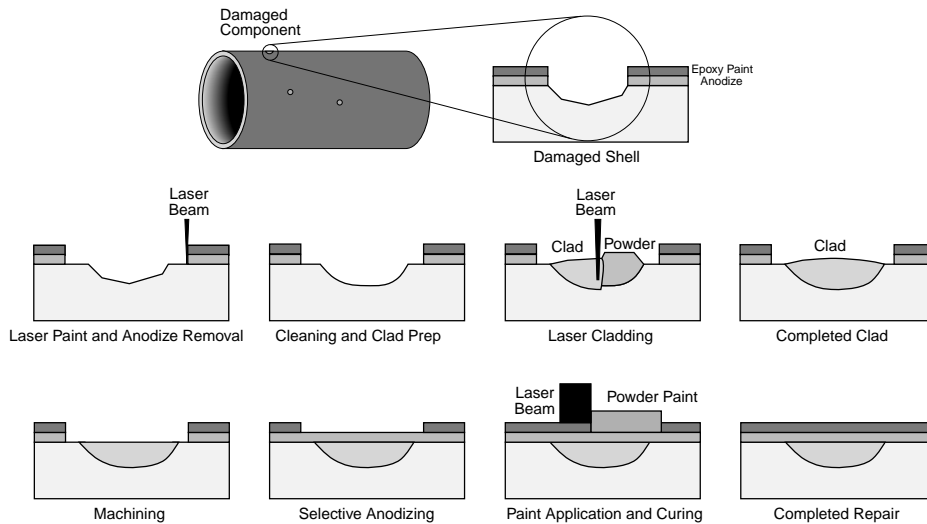
The Mk48 torpedo.



Laser repair of shell components at the NUWC-Keyport laser repair facility.

dimensional tolerances, making the part unfit for service. The third factor is the powder epoxy paint process. This process employs a two step heating process that is within the aging temperature range for most aluminum alloys. Each powder epoxy application cycle alters the mechanical properties of the alloy; eventually the material does not have sufficient properties to meet the design requirements.

Laser processing offers several advantages over the conventional repair process. Laser processing allows for repairs to be made locally at the damage site instead of on a global basis. Two Nd:YAG lasers are employed in the repair process, a Q-switched laser and a 3 kW continuous wave (CW) laser. The Q-switched laser is used for coating removal; its high peak power ablates the coating material without damaging the underlying material. Both the powder epoxy paint and the anodized coating can easily be removed. The parameters can be adjusted to remove both coatings one layer at a time. The 3kw continuous wave laser is used to fuse aluminum powder to



Laser repair process for torpedo shell components.

the damaged substrate. The process is rapid, which reduces degradation of the material in the heat-affected zone. This rapid processing also allows for the repair of aluminum alloys such as 7075, which are generally not amenable to fusion welding due to cracking. The repair is a full metallurgical bond that is structurally integrated with the substrate. The 3 kW laser will also be used to cure the powder epoxy paint at the repair area, thus completing the “spot” repair process.

A 3 kW laser system has been operational at the Naval Undersea Warfare Center since January of 2000. Torpedo components valued at over \$700K have been repaired and returned to fleet use. A Q-switched laser is currently being installed and is expected to be operational in the near future.

## Vertical Launch System

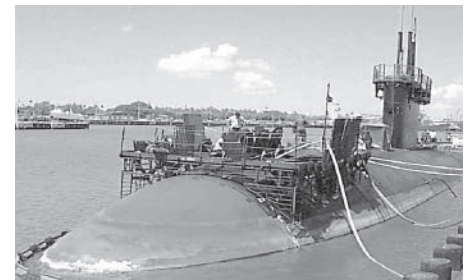
U.S. Navy submarine SSN 688 Class Vertical Launch System (VLS) launch tubes are experiencing corrosion damage at sealing surfaces. Repairing this damage requires on-site electroplating, which is at best a temporary fix. Often the damage cannot be determined until testing during weapons loading has been performed, necessitating removal of the weapon, movement of the vessel to a repair area, and expenditure of significant time to effect a plating repair. The plating process is expensive, time-consuming, cumbersome, and generates hazardous

material. In addition to a high cost (up to \$300K per vessel) for typical plating repairs, the problem can possibly affect vessel readiness, especially if a large number of tubes are involved. As the fleet ages, the problem can be expected to worsen, with increasing numbers of tubes requiring this repair.

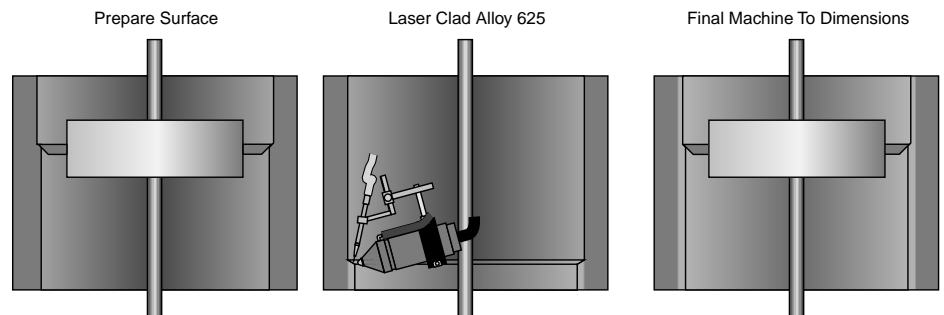
Corrosion is occurring in VLS tube areas that were clad with Alloy 625 by a submerged arc process during new construction. This process can have high dilution with the base metal, which alters the alloy composition of the cladding, making it more susceptible to seawater corrosion than the undiluted alloy. Laser cladding is an alternative to traditional methods of welding or plating, and has been shown to provide exceptionally low dilution, and therefore higher corrosion performance of the cladding material. Testing of laser cladding has shown that dilution occurs

in only the first 0.002 inch of thickness, far less than that shown by conventional methods. At the same time, the tube is a precision-machined weapon, and any repair technique must not cause distortion to critical surfaces and tolerances. Once again, laser cladding can provide a solution, since the heat input of laser methods is lower than any other process providing a metallurgical bond.

Much of the fundamental metallurgical testing of laser cladding with Alloy 625 has already been performed, but it will be necessary to develop procedures to perform cladding within the confined space of VLS tubes. In this project, the team of ARL and the Naval Undersea Warfare Center – Keyport Division will adapt existing COTS portable boring equipment for the laser repair. This will allow a repair crew to pre-machine, perform the laser cladding, and finish machine the new cladding single set-up. Savings accruing from the use of this method hope to exceed \$250K per vessel, compared to repair by plating. Once the cladding is done, it is expected that plating these tubes will become a thing of the past.



Repair of VLS launch tubes at dockside.



In-situ laser cladding process for VLS tubes.



iMAST Director, Bob Cook, discusses project efforts with Captain Ken Heffernan who is currently on assignment with the National Reconnaissance Office in Washington, D.C.

### DMC 2000 Concludes

Members of iMAST just completed participation in Defense Manufacturing Conference 2000, which was held in Tampa, Florida. Once again, leaders from government, industry and academia assembled to exchange perspectives and information relative to manufacturing technology, sustainment, and industrial modernization. This year's theme, "Foundation for Global Security" provided insight into how to pave the way toward future successes in the manufacture and sustainment of both military and commercial products. Featured speakers included Dr. Delores Etter, Deputy Under Secretary of Defense (Science and Technology) who addressed "Implications of Defense Advanced Manufacturing Technology for Economic and Military Security."

In addition to providing an exhibit booth featuring iMAST's ManTech and Repair Technology efforts, ARL's Dr. Tim Eden provided an overview on "Advanced Manufacturing Processes for the Advanced Amphibious Assault Vehicle (road wheel and track pins) as part of the sustainment readiness working group session. Program managers from the Naval Undersea Warfare Center (Keyport Division) and Puget Sound Naval Shipyard, also provided overviews on laser repair and cladding processes that have been successfully completed based on iMAST ManTech project efforts at ARL Penn State.

DMC 2001 will be held in Las Vegas, Nevada next year 26-29 November. Make plans now to register and be sure to visit our iMAST exhibit booth.

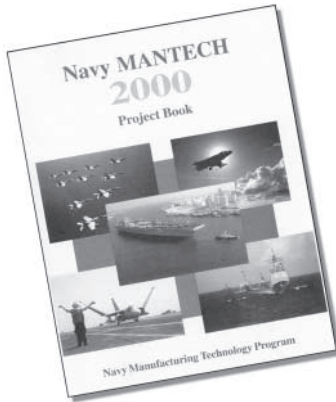
### DoD ManTech at Fifty

The objective of the Defense Manufacturing Technology (ManTech) Program is to improve the affordability of Department of Defense systems by transitionioning new and improved manufacturing processes for application across the weapon system life cycle. As the DoD ManTech Program prepares to celebrate 50 years of service to the nation, perhaps it is appropriate to notes its legacy of "firsts" here:

- \* Numerically controlled machine tools
- \* Automatically programmed machine tool industry-wide standard language
- \* Basic processes and tools for microelectronics manufacture
- \* Retirement-for-Cause inspection of critical aircraft engine components
- \* Net-shape manufacturing processes for aluminum, titanium and superalloy parts
- \* Rapid three-dimensional nondestructive inspection for large rocket motors
- \* Basic process modeling methodologies
- \* Integrated computer-aided design and manufacturing concepts and methods
- \* Automated combat rations, clothing and ammunition manufacturing processes
- \* Environmentally-safe paint removal for aircraft and ships
- \* Night-vision device process methods
- \* Introduction of advanced manufacturing processes for composite structures
- \* Aerospace industry-wide adoption of "Lean" culture and concepts

What is the current vision for ManTech? ManTech must realize a responsive, world-class manufacturing capability to affordably meet the warfighter's needs throughout the defense system life cycle. How will they accomplish that? They will develop a strategic approach that creates a timely, responsive, and balanced program, promotes world-class manufacturing capabilities, ensures satisfied customers, and maintains a track record of success. For more information on the Joint Defense Manufacturing Program, visit their web site at <<http://mantech.iitri.org>>.





## **Navy ManTech 2000 Project Books Available**

The 2000 issue of the Navy Manufacturing Technology Project Book is now available for distribution. CD-ROM copies are also available. For more information on how you can obtain copies, contact the Office of Naval Research Industrial and Corporate Programs Detachment, Building 10, 700 Robbins Avenue, Philadelphia, PA 19111-5078. You can also visit the Navy ManTech web site at: <<https://mantech.pti.com>>.



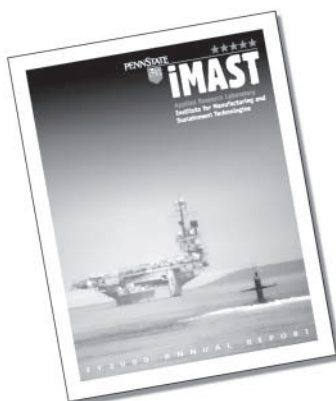
## **Navy ManTech Points of Contact Book Available**

The 2000 Navy ManTech Points of Contact booklet is now available for distribution. The booklet is a handy guide for contacting various members of the Navy Manufacturing Technology Program, both within the Systems Commands, Fleet, and the Navy ManTech Centers of Excellence. Copies of this booklet are also available through the Office of Naval Research Industrial and Corporate Programs Detachment, Building 10, 700 Robbins Avenue, Philadelphia, PA 19111-5078. The Navy ManTech web site <<https://mantech.pti.com>> also contains the listed information.



## **How Can My Company Work With Navy ManTech?**

A number of calls from industry have prompted the creation of a pamphlet entitled "How can my company work with Navy ManTech?" Give us a call and we'll make sure a copy is sent to you. You may also visit the Navy ManTech web site to learn more. We look forward to hearing from you. We can share our insight and provide you counsel in your efforts to team up with a systems command and a Navy ManTech Center of Excellence. Call our administrator, Greg Johnson, at (814) 865-8207 for more information and details.



## **iMAST FY-00 Annual Report Available**

The FY-00 iMAST annual report is available on-line at <[www.arl.psu.edu/areas/imast/imast.html](http://www.arl.psu.edu/areas/imast/imast.html)>. A limited number of hard copies are also available on a first call-first serve basis. Contact the iMAST research administrator, Greg Johnson, by phone at (814) 865-8207, or by e-mail at <[gjj1@psu.edu](mailto:gjj1@psu.edu)> for requests. The annual report summarizes Navy ManTech project activities. It also provides highlights ARL unique capabilities, facilities, and points of contact.

## CALENDAR OF EVENTS

<b>28–30 Jan 2001</b>	NDIA Tactical Wheeled Vehicle Conference	Monterey, CA
<b>3–5 Apr</b>	AW&ST Maintenance, Overhaul and Repair Conference	Dallas, TX
<b>10–12 Apr</b>	Navy League Sea-Air-Space Expo 2001	Washington, D.C.
<b>17–18 Apr</b>	Tech Trends 2001	Atlantic City, NJ
<b>9–11 May</b>	American Helicopter Society Forum 57 ★★★★★ visit the iMAST booth	Washington, D.C.
<b>15–17 May</b>	NASTC 2001	Dayton, OH
<b>22–23 May</b>	Materials and Manufacturing Advisory Board Meeting	State College, PA
<b>Fall TBA</b>	Second Annual ONR Naval-Industry R&D Conference ★★★★★ visit the iMAST booth	Washington, D.C.
<b>10–13 Sep</b>	NDIA Joint Undersea Warfare Technology Conference	Groton, CT
<b>18–20 Sep</b>	Marine Corps League Expo ★★★★★ visit the iMAST booth	Quantico, VA
<b>24–26 Sep</b>	NDIA Combat Vehicles Conference	Ft. Knox, KY
<b>TBD Oct</b>	AUSA Expo	Washington, D.C.
<b>29 Oct–2 Nov</b>	NDIA Expeditionary Warfare Conference	Panama City, FL
<b>26–29 Nov</b>	Defense Manufacturing Conference 2001 ★★★★★ visit the iMAST booth	Las Vegas, NV

### Quotable

*“The rapid pace of civilian technology is limited to a few critical areas. It is not universal. The private sector does not run wind tunnels. There is no market for torpedeos. People who say we should rely on the private sector are, I think, distorting the real fact of the matter. We still have to make heavy investments into the development of knowledge that has foreseeable military application.”*

—Hans Mark, DoD Director of Defense Research and Engineering

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